GPS water vapor tomography with flexible spatio-temporal constraints

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Recently, several methods for GPS water vapor tomography have been proposed. Usually, the model space is divided into 3-D cells and the water vapor amount in each cell at a time window is estimated from GPS observational data. To improve spatial resolution, a long observation time window, say 2 hours, is required (Hirahara,2000). Or, assuming wind speed and direction, moving cell method is proposed (Seko et al.,2000). In a local scale, the temporal change in water vapor is expected to be very rapid, so that we need to get high temporal resolution.

Here, we propose a new method of GPS water vapor tomography to estimate water vapor amount in each cell at each epoch. To stabilize the solution, we use all possible other observations than GPS and physical constraints. Other observational data are vertical profiles of water vapor at epochs derived from radio sonde observations. Based on sonde or other observations, assuming wind speeds and directions at epochs, we apply constraints that the water vapor amount in cell (x1,y1,z1) at epoch t1 is equal to that in cell (x2,y2,z2) at epoch t2. And, we apply spatio-temporal smoothness constraints with first order smoothness. Adding these all constraints with appropriate weights to original observational equations, we solve these augmented observational equations in a least squares sense. Since we estimate water vapor amount in 3-D cells at all epochs simultaneously, the number of unknown parameters is too huge to solve with usual matrix inversion methods. Then, we use a tomographic inversion technique, LSQR, which is one of iterative solvers.

We applied the method to the Tskuba GPS campaign data during 0-1 hour on Oct. 10th, 2000. We tried to estimate at each 10, 5, 2.5, 1 minutes interval. The number of observations, of the unknown parameters, of initial model from sonde observations, wind data, space and time smoothness constraints are 1494, 6276, 6276, 1397, 11671, 4985 for 10 minutes interval, and 13550, 55813, 55813, 316537, 103913, 52953. The obtained results are dependent on the choice of weightings and epoch intervals. Though the proposed new method is very flexible to use all kind of observations and constraints, we need to examine how to assign weight and epoch interval.